NATURAL ENVIRONMENT RESEARCH COUNCIL
Institute of Geological Sciences

The geology of the Severn barrage area

A report prepared by the Institute of Geological Sciences
for the Department of Energy

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by G. W. Green and B. N. Fletcher

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SUMMARY

An account is given of the onshore and offshore geology of the Severn Barrage area, largely compiled from unpublished Institute of Geological Sciences work in the estuary and on land. The most important preliminary result is that much of the area of the barrage has bedrock exposed at the seabed and is not covered by drift, contrary to evidence available in the report of the Select Committee.

Proposals are made for a more detailed survey.

ACKNOWLEDGEMENT

A number of units from the Institute of Geological Sciences have contributed information which has been used to compile this report.

The continuous reflection profiling records in the offshore area were taken by the Radioactive and Metalliferous Minerals Unit on two cruises in the Bristol Channel, and the sampling was by the Continental Shelf Unit 1. Dr D.B. Smith and Dr R.A. Waters (South Wales and Welsh Marches Unit) contributed to the geology of the Lavernock Point area, whilst the engineering references were supplied by the Engineering Geology Unit.

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The offshore geology in the area of the Severn Barrage scheme is not known in detail, but the rock types are the same as those that occur in the adjacent land areas. The onshore geology, which is well known, is very relevant to the barrage scheme and is discussed first.

Much of the work included in this report is based upon recent work by the Institute of Geological Sciences (IGS) and has not yet been published.

Onshore Geology

The geological successions etc are essentially similar on each side of the Bristol Channel. They comprise, in descending order:

	Thickness m
QUATERNARY	
Drift deposits of sand, gravel and estuarine clays and silts	up to 35
MESOZOIC	
JURASSIC	
Lower Lias	
Mudstones and shales with some argillaceous limestones (semicostatum Zone)	about 75
Sinemurian	
South side of Channel-Fissile shales and mudstones with a few limestones in middle and upper parts. Alternating shales, mudstones and massive limestones in lower part. North side of Channel-Massive limestones with thin shales (bucklandi Zone)	40-50
Hettangian	
Alternating thin limestones and shaley mudstones, though limestone/shale ratio variable (angulata Zone)	15-50
Shales and marly mudstones with a few layers of limestone nodules (liasicus Zone)	12-25
Alternating limestones and soft shales (planorbis Zone)	about 14
TRIASSIC	
Rhaetic	
White Lias and Cotham Beds	
Calcareous mudstones, shales with subordinate hard fine-grained limestones especially in top 1-$1\frac{1}{2}$ m (White Lias)	3-4
Westbury Beds	
Soft dark grey to nearly black fissile pyritous mudstones and shales with subordinate impure limestones and bands of fibrous calcite	7-13
Keuper	
Tea Green and Grey Marls	
Alternating greenish grey, grey and pink mudstone and siltstones with discrete layers and nodular masses and veins of gypsum ($CaSO_4$) and more rarely celestite ($SrSO_4$)	16-31
Red Marls	
Alternating red and some green mudstones and siltstones with discrete nodular layers and veins of gypsum and more rarely celestite in uppermost parts; monotonous red silty mudstones with green patches forming main part of formation	+200
Dolomitic Conglomerate	
Limestone conglomerates with beds of red sandstone and mudstone	
– Major Unconformity –	
PALAEOZOIC	
CARBONIFEROUS	
Carboniferous Limestone	
Hard, massive to bedded grey limestones and dolomites with some thin shales in parts	about 1000

Notes on succession

Drift deposits Inland, on both sides of the Bristol Channel, up to 30 m of soft unconsolidated muds, silts and sands with some peat levels, are widespread. Details of successions can be supplied if necessary. Their very low bearing strengths give rise to considerable engineering problems.

Lower Lias The limestones are hard to very hard, fine-grained and rather argillaceous, with individual beds ranging in thickness from 1-2 cm to as much as 0.8 m. The limestone nodules are similar to the limestone beds. The fossil content of the Lias is such as to enable even quite small samples to be related to the general succession. Pyrite is not uncommon. All the beds are calcareous to some extent.

Rhaetic The White Lias comprise relatively pure, fine-grained, hard to very hard splintery limestones. The Cotham Beds are weakly calcareous. The mudstones and shales of the Westbury Beds are non-calcareous and pyritous.

Tea Green, Grey and Red Marls are slightly calcitic and dolomitic. The siltstones are harder than the intervening marls and locally may approach silty limestone in composition. Apart from colour differences, all these formations are essentially similar in rock type.

Dolomitic Conglomerate This is a fossil scree and fan deposit composed of Carboniferous Limestone debris and is only found adjacent to outcrops of Carboniferous Limestone. It passes laterally into the Red Marls, generally within 100 m of the Limestone outcrops.

Unconformity below the Mesozoic rocks This represents an old and very irregular land surface. Locally the Triassic rocks fill fissures up to 1-3 m wide in the underlying Carboniferous Limestone. The plane of the unconformity is typically very steep with gradients ranging from 1 in 1 to 1 in 3. Patchy dolomitisation of the Carboniferous Limestone may be locally important especially near the junction with the Triassic rocks - this results in a rather variable degree of hardness of the limestone and may result in increased porosity (in the dolomitised parts).

Carboniferous Limestone (for structure see below)

a. Steep Holm. The succession here ranges from massive to well-bedded limestones. Trias-filled joints associated with minor galena-baryte mineralisation are particularly evident in the south-west corner of the island.

b. Flat Holm. The succession is similar to that on Steep Holm but includes in addition a unit some 35-40 metres in total thickness, comprising massive limestone beds (2-7 m) alternating with thinly bedded mudstone and dolomite bands (1-5 m).

c. Wolves. Rocks of massive limestone exposed at low water.

Notes on the structure

GENERAL: There is a marked discrepancy between the magnitude of the structures in the Carboniferous rocks and those in the overlying Mesozoic rocks. The former are characterised by strong East-West fold axes and associated thrust faults and northerly trending high-angle faults which cut all the other structures. The structures in the Mesozoic rocks in contrast are gentle with broad folds with dips ranging from a few degrees to rarely more than 10°. These folds often appear to coincide with the folds in the underlying Carboniferous rocks but are much gentler. Faults are common in the Mesozoic rocks but usually small (many are too small to show on the accompanying map) though occasionally may be 30 m or more in throw. The dominant trends are easterly, though others with a northerly trend are also important locally (see Geological Survey maps of adjoining areas).

a. Steep Holm. A sharp monoclinal fold runs along the northern side of the island, the dip upturning sharply northward to about 70° from the ruling dip of about 20-25° farther south. The rocks are strongly shattered where the change of dip occurs. The structure in the South-West corner and along the South side of the island is complex, with numerous East-North-East trending folds and much associated shattering. The movement has occurred beneath a low-angle bedding-plane fault or slide which cuts obliquely across the island and runs into the sea in the South-East corner of the island. The structural continuity with the mainland is uncertain and it appears probable that the intervening Mesozoic rocks mask an area of considerable structural complexity in the Carboniferous rocks.

b. Flat Holm. The major feature is an East-North-East aligned anticline pitching gently to the South-West but there are also many small folds and small faults associated with the banded limestone-shale sequence noted above. An important thrust dipping 45° to the South-South-East repeats the latter sequence in the area to the south of the lighthouse.

c. Wolves. The limestone appears to have a gentle northerly dip.

Offshore Geology

The Institute of Geological Sciences have recently carried out some continuous reflection profiling supplemented by gravity coring in part of the area of both the Wilson and Shaw schemes for a proposed Severn Barrage.

The most important preliminary result of this survey is that much of the area of the barrage has bedrock exposed at the seabed. This is contrary to para 15 page 10 of the Select Committee report (1975), which states that 'the limited information so far available on the Severn Estuary bed indicates that loose deposits overlie much of the barrage site'.

A narrow belt of sand and mud extends southwestwards from Steep Holm to Culver Sands, and in areas of relatively restricted currents near the coast, superficial deposits occur. This is particularly seen on the eastern margin of the estuary where Sand Bay and Bridgewater Bay are largely mud covered. Elsewhere in the estuary, sampling suggests that there is either rock at the seabed or the overlying sands and gravels are less than 0.5 metre thick but further sampling is needed to confirm this.

The major Mesozoic structural features offshore are the two east-west trending anticlines with their axes passing through the islands of Flat Holm and Steep Holm (see Fig. 3). These fold axes are prolongations of the Brean Down and Middle Hope structures of the Mendips. Numerous faults occur on the shallow seismic records but, due to the wide spacing of some of the lines, it is difficult to continue these faults from one seismic line to another with any certainty.

The main rock types which will be encountered in the barrage scheme have been given (p. 1) in the geological succession of the area.

The Carboniferous Limestone crops out in the core of the anticlines and forms the islands of Steep Holm, Flat Holm and the Wolves, where

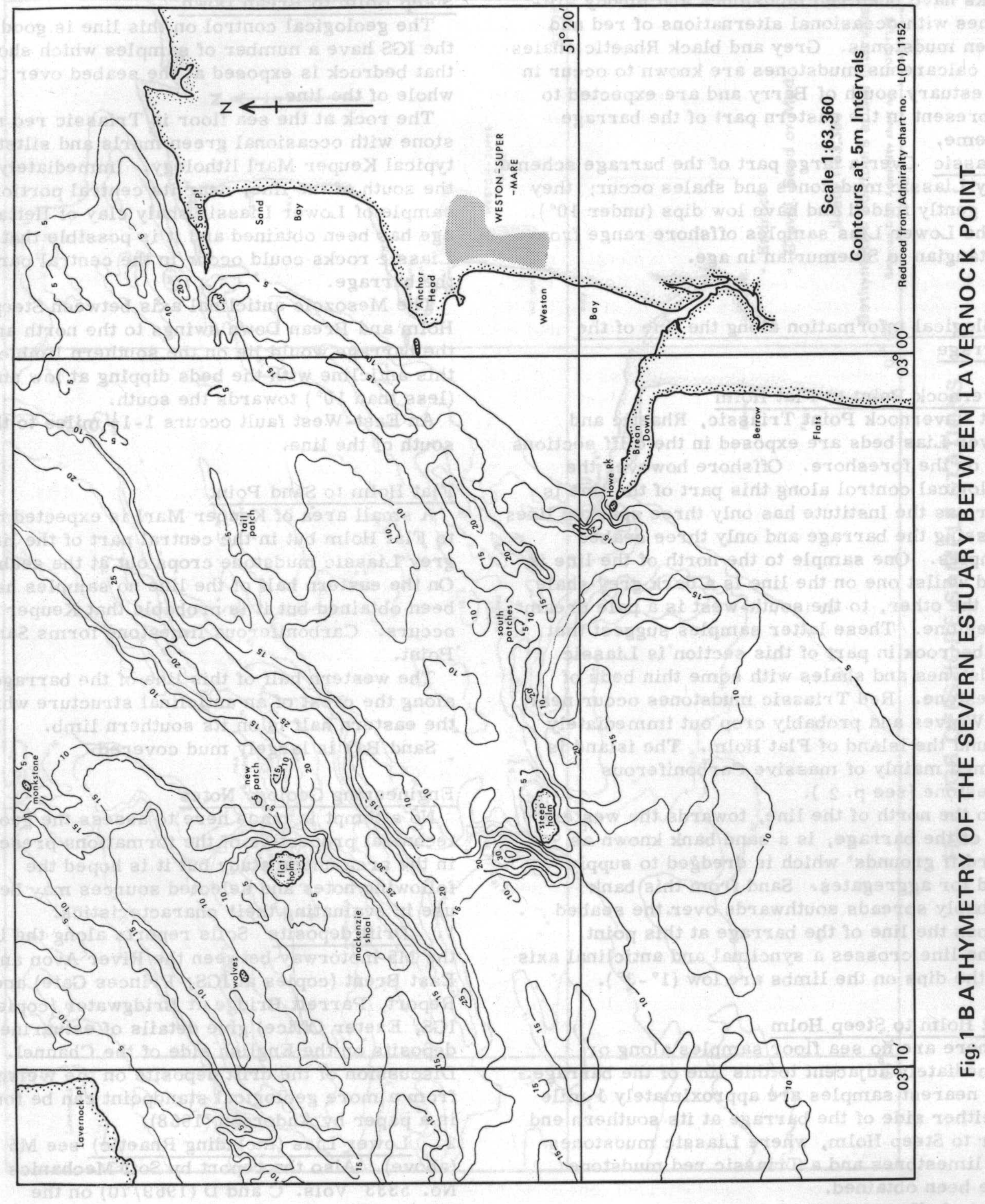

Fig. 1 BATHYMETRY OF THE SEVERN ESTUARY BETWEEN LAVERNOCK POINT AND WESTON-SUPER-MARE

the dip on the limbs of the folds ranges from 15° to 70°.

The limestone is restricted to the immediate area of the islands and is thought to occur in only very small areas elsewhere along the anticlinal axes.

Triassic Six gravity core samples of Keuper lithology have been collected between Steep Holm and Brean Down. All the samples of Triassic rocks have been red mudstones and muddy siltstones with occasional alternations of red and green mudstones. Grey and black Rhaetic shales and calcareous mudstones are known to occur in the estuary south of Barry and are expected to be present in the eastern part of the barrage scheme.

Jurassic Over a large part of the barrage scheme, grey Liassic mudstones and shales occur; they are gently folded and have low dips (under 10°).

The Lower Lias samples offshore range from Hettangian to Sinemurian in age.

Geological information along the line of the Barrage

Lavernock Point to Flat Holm

At Lavernock Point Triassic, Rhaetic and Lower Lias beds are exposed in the cliff sections and on the foreshore. Offshore however the geological control along this part of the line is poor, as the Institute has only three sparker lines crossing the barrage and only three seabed samples. One sample to the north of the line is sand whilst one on the line is a dark grey shale and the other, to the south-west is a pale cream limestone. These latter samples suggest that the bedrock in part of this section is Liassic mudstones and shales with some thin beds of limestone. Red Triassic mudstones occur near the Wolves and probably crop out immediately around the island of Flat Holm. The island is formed mainly of massive Carboniferous limestone (see p. 2).

To the north of the line, towards the western end of the barrage, is a sand bank known as 'Cardiff grounds' which is dredged to supply sand for aggregates. Sand from this bank probably spreads southwards over the seabed across the line of the barrage at this point.

The line crosses a synclinal and anticlinal axis but the dips on the limbs are low (1°-3°).

Flat Holm to Steep Holm

There are no sea floor samples along or immediately adjacent to this line of the barrage. The nearest samples are approximately 1 mile on either side of the barrage at its southern end near to Steep Holm, where Liassic mudstones and limestones and a Triassic red mudstone have been obtained.

The shallow seismic information suggests that almost all this part of the barrage is over Lower Liassic mudstones except in the vicinity of Steep Holm where Keuper marls surround the Carboniferous Limestone which forms the island.

An area of sand in shallow water East-North-East of Flat Holm, known as 'New Patch', is dredged for sand, as is the 'Mackenzie shoal' to the South-West of the island, (Fig. 1).

Some faulting has been observed on shallow seismic records but is thought to be of a minor nature.

The Jurassic rocks between Flat Holm and Steep Holm are everywhere dipping at low angles (2°-3°).

Steep Holm to Brean Down

The geological control on this line is good as the IGS have a number of samples which show that bedrock is exposed at the seabed over the whole of the line.

The rock at the sea floor is Triassic red mudstone with occasional green marls and siltstones - typical Keuper Marl lithology. Immediately to the south of the line, near its central portion, a sample of Lower Liassic shaly clay of Hettangian age has been obtained and it is possible that Liassic rocks could occur in the central part of the barrage.

The Mesozoic anticlinal axis between Steep Holm and Brean Down swings to the north and the barrage would lie on the southern limb of this anticline with the beds dipping at low angles (less than 10°) towards the south.

An East-West fault occurs 1-1½ miles to the south of the line.

Flat Holm to Sand Point

A small area of Keuper Marl is expected near to Flat Holm but in the central part of the line, grey Liassic mudstone crops out at the seabed. On the eastern half of the line no samples have been obtained but it is probable that Keuper Marl occurs. Carboniferous limestone forms Sand Point.

The western half of this line of the barrage runs along the crest of an anticlinal structure whilst the eastern half is on its southern limb.

Sand Bay is largely mud covered.

Engineering Geology Notes

No attempt is made here to assess the geotechnical properties of the formations present in the area under study but it is hoped the following notes and selected sources may be of use in evaluating their characteristics.

1. Drift deposits Soils reports along the line of the M5 motorway between the River Avon and East Brent (copies at IGS, Princes Gate) and M5 Report, Parrett Bridge at Bridgwater (copies at IGS, Exeter Office) give details of estuarine deposits on the English side of the Channel. Discussion of the drift deposits on the Welsh side from a more geological standpoint can be found in a paper by Anderson (1968).

2. Lower Lias (including Rhaetic) see M5 Report (above). Also the report by Soil Mechanics Ltd No. 5333 Vols. C and D (1969/70) on the Edithmead to Huntsworth section of the M5 (copies at IGS, Exeter Office). The Hinkley Point Nuclear River Station was based on these rocks (but not extending down to the Rhaetic) and a detailed report (not in possession of IGS) was prepared by Soil Mechanics Ltd, Bracknell for the CEGB. Various parameters of use in evaluation of the soils

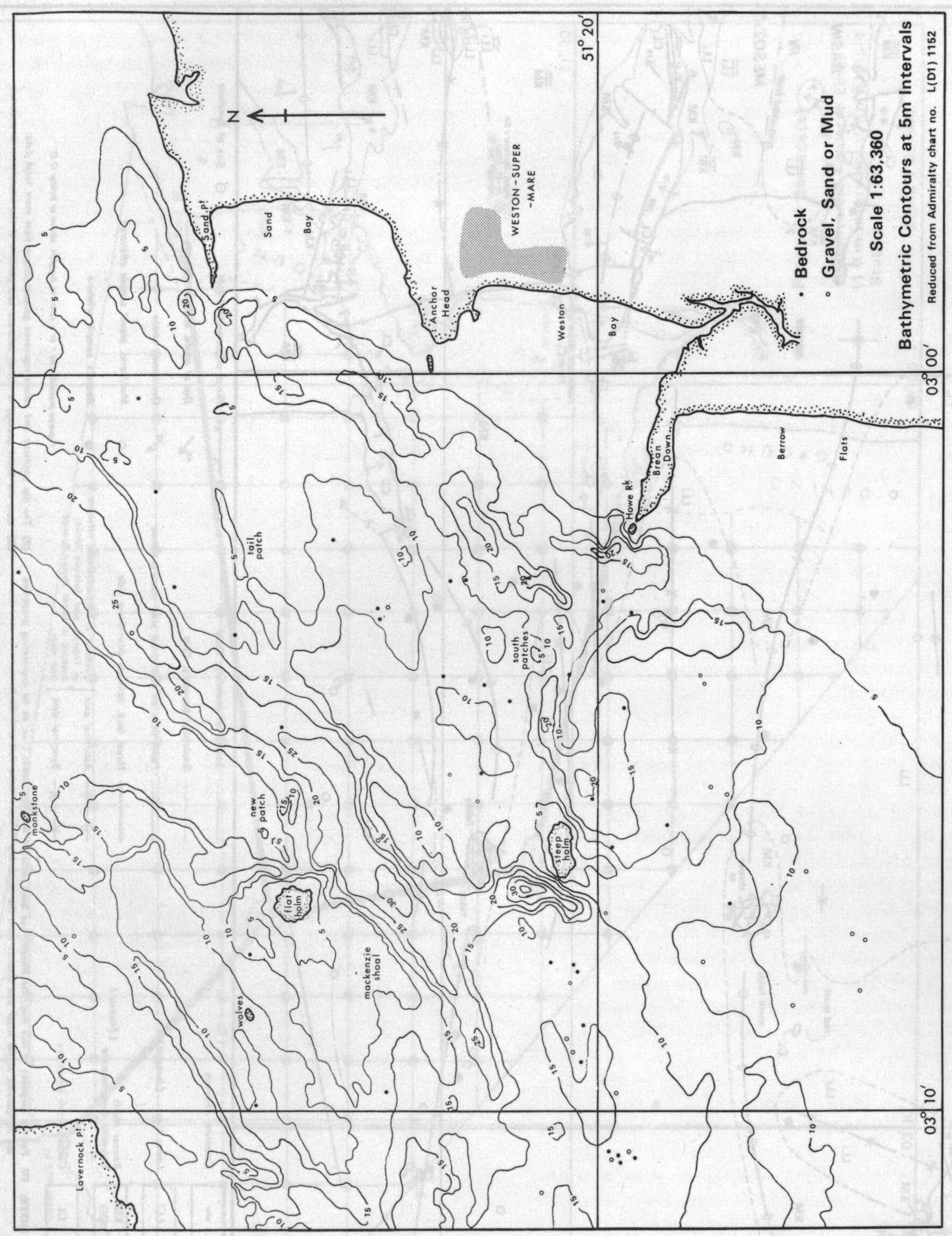

Fig. 2 IGS OFFSHORE SAMPLE STATIONS

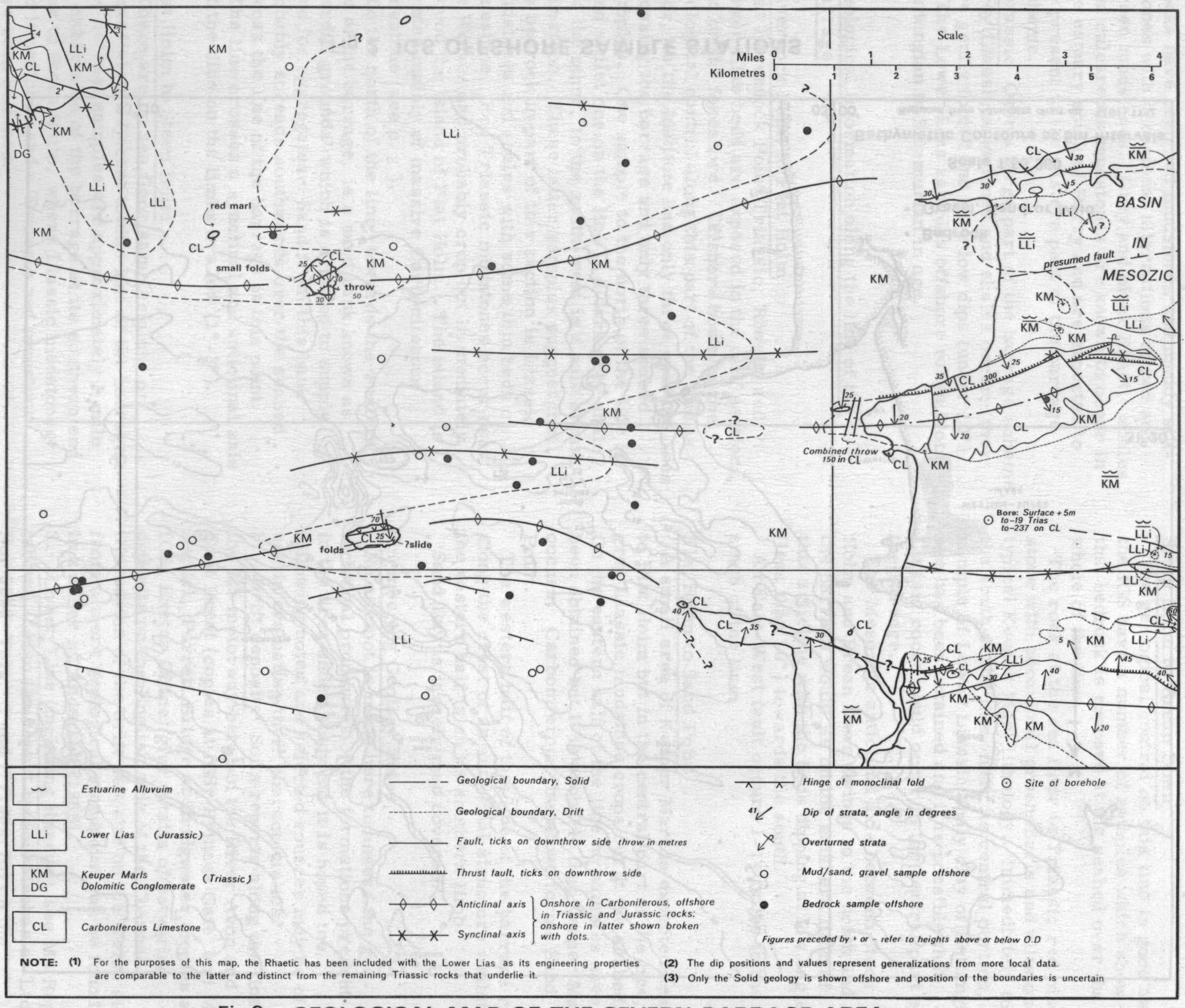

Fig.3 GEOLOGICAL MAP OF THE SEVERN BARRAGE AREA

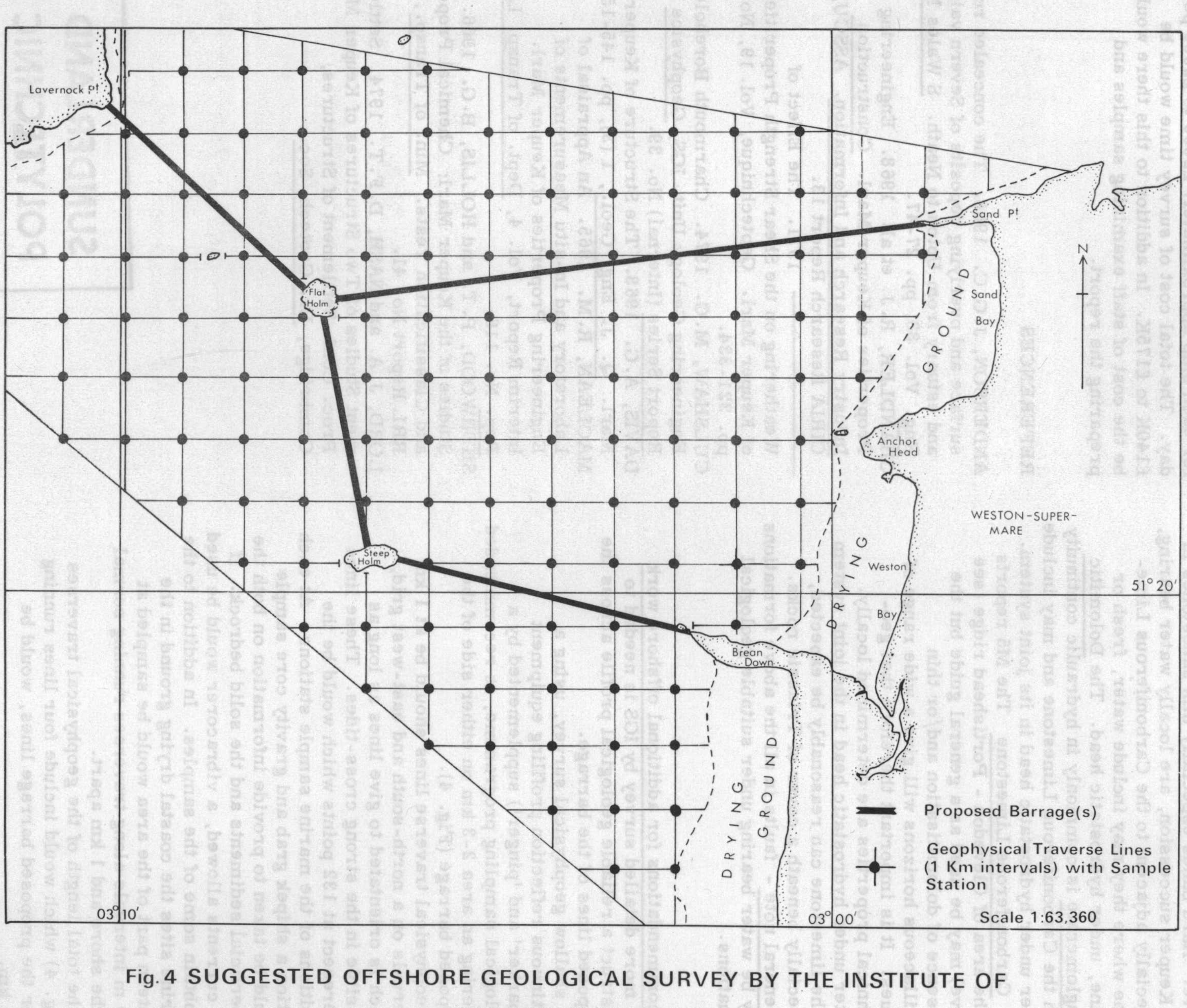

Fig.4 SUGGESTED OFFSHORE GEOLOGICAL SURVEY BY THE INSTITUTE OF GEOLOGICAL SCIENCES

characteristics of Lower Lias determined by IGS are given by Culshaw (1974). These rocks are not significantly water bearing.

3. Keuper Marl This formation is well-known geotechnically and the following papers amongst others will be found useful - Chandler et al 1968, Chandler 1971, Davis 1968, Sherwood and Hollis 1966, Lord and Nash 1974, Maclean 1965. They are also included in the various M5 Reports listed above. Hard bands especially thin sandstones in the Keuper succession, are locally water bearing, especially adjacent to the Carboniferous Limestone where they may include water, fresh or saline, under hydrostatic head. The Dolomitic Conglomerate is commonly in hydraulic continuity with the Carboniferous Limestone and may include water under hydrostatic head in its joint system.

4. Carboniferous Limestone The M5 reports in the area of Clevedon - Portishead ridge (see above) may be used as a general guide but the presence of dolomitisation and/or thin argillaceous horizons will give a wide range of values. It is important therefore that geotechnical properties are determined locally. Water under hydrostatic head in the joint system of the limestone can reasonably be expected, especially beneath a cover of Triassic rocks.

General note - faults in all the above formations may be water bearing under suitable geological situations.

Recommendations for additional offshore work

A more detailed survey by IGS is needed to construct a reliable geological profile across the proposed lines of the barrage.

A shallow geophysical survey, using a continuous reflection profiling equipment ('sparker' and 'pinger') supplemented by a geological sampling programme, is recommended covering an area 2-3 km on either side of the proposed barrage (Fig. 4).

Geophysical traverse lines should be at 1 km intervals on a north-south and east-west grid, which is orientated to give lines as long as possible in the strong cross-tides. These lines interesect at 132 points which would be the positions of the marine sample stations. At each station a shipek grab and gravity core sample would be taken to provide information on both the superficial sediments and the solid bedrock. If the currents allowed, a vibracorer would be used to obtain some of the samples. In addition to the marine sites the coastal drying ground in the eastern part of the area would be sampled at 500 m intervals along traverses running normal to the shore and 1 km apart.

The total length of the geophysical traverses (Fig. 4) which would include four lines running over the proposed barrage lines, would be 294 km.

Estimated time for survey

Geophysical survey	4 to 5 weeks
Marine sampling	4 to 5 weeks

Approximately 30 per cent of this time is allocated to mobilising and demobilising the ship, sea-trails, personnel changeover days, bad weather and breakdowns. Sampling of the coastal flats either on foot or by small inflatable boat would take 10 days and would be independent of weather conditions.

Cost

The geophysical and sampling programme would be carried out from separate ships. Cost for each ship approximately £2000 to £2500 per day. The total cost of survey time would be £140K to £175K. In addition to this there would be the cost of staff examining samples and preparing the report.

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